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Bringing Human-Centredness to Technologies for Buildings

An agenda for linking new types of data to the challenge of sustainability

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Published in:
CHItaly '21

DOI (link to publication from Publisher):
10.1145/3464385.3464711

Publication date:
2021

Document Version
Early version, also known as pre-print

Link to publication from Aalborg University

Citation for published version (APA):
Vite, C., Horvath, A-S., Neff, G., & Møller, N. L. H. (2021). Bringing Human-Centredness to Technologies for Buildings: An agenda for linking new types of data to the challenge of sustainability. In A. De Angeli, L. Chittaro, R. Gennari, M. De Marsico, A. Melonio, C. Gena, L. De Russis, & L. D. Spano (Eds.), *CHItaly '21: Proceedings of the 14th Biannual Conference of the Italian SIGCHI Chapter* (pp. 1-8). [10] Association for Computing Machinery. https://doi.org/10.1145/3464385.3464711

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Bringing Human-Centredness to Technologies for Buildings

An agenda for linking new types of data to the challenge of sustainability

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The politics around data and power relations related to technologies for buildings is a new area for HCI. This paper proposes an agenda for linking new types of data to the challenge of sustainability, bringing human-centredness to a particular tool for design and engineering professionals, Building Information Modeling (BIM). BIM is the preferred technology platform for coordination and collaboration in architectural design and construction. BIM contains different types of data and information about a building including 3D (geometry), 4D (time), 5D (cost), 6D (facility management) and 7D (sustainability). Once constructed, this 'digital twin' of the building allows for adding new services and for stakeholders interacting with the building design through through sensors, immersive experiences and virtual, augmented and mixed realities. As a socio-technical software process, BIM also accommodates diverging agendas on design and construction for sustainability, and these diverging concepts about 'sustainability' "live" in different places with implications for the resulting BIM models. Based on our findings, we suggest a better integration and coherent representation of such issues of interest not only to new services but also stakeholders into the different forms of data (e.g. facilities management and sustainability). We argue for a stronger shared understanding of BIM as a platform for engaging with technologies designed for interacting with buildings and push agendas of sustainable construction.

CCS Concepts: • **Human-centered computing → Empirical studies in collaborative and social computing**.

Additional Key Words and Phrases: Building Information Modeling, Digitized Construction, Sustainability, Common Data Environments

ACM Reference Format:
Clara Vite, Anca-Simona Horvath, Gina Neff, and Naja L. Holten Møller. 2021. Bringing Human-Centredness to Technologies for Buildings: An agenda for linking new types of data to the challenge of sustainability. In . ACM, New York, NY, USA, 13 pages. https://doi.org/10.1145/1122445.1122456

1 INTRODUCTION

For a decade, HCI and CSCW research has been increasingly expanding its agenda to address how to mitigate the problems of climate change and environmental sustainability [12] [24]. Human-Building Interaction [1] and digitized construction [11] are both examples of how the broader HCI and CSCW communities are engaging with the challenge of working towards sustainability through digitalization. These include how energy consultants push for sustainability choices [15] and how team organization matters for energy modelling and engineering. One of the challenges of Building Information Modelling (BIM) is that the 'common' data model required for digital construction often does not match the "loosely coupled" nature of the work [38] [33]. The result is difficulty coordinating work across communities of practice

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Manuscript submitted to ACM

with a set of digital technologies that could help in designing more sustainable building solutions. Once a building is constructed and ready to use, digitized BIM models can be reused, for example in facility management [7] and coupled to new services that allow for interaction with the building. One example is how sensor data coupled with the digital building model allows for the 'smart' regulation of temperature in a building at scale. However, such understandings of sustainability in professional design and engineering often pay little attention to the potential contradictions that HCI scholars might identify in these kinds of data and the challenges individuals and teams face in translating these data into action [12], [7], [9].

Scholars researching the politics around data and technologies for building suggest design should connect to the needs "from below" [8]. Professional understandings of how information technologies can improve building sustainability often neglects the risks entailed in everyday interactions with smart buildings. For example, incidental data captured through the 'smart' infrastructure of a public housing development project resulted in pushing control and regulation of individuals and families who depend on such subsidized housing solutions [23], and the challenges of smart cities are rarely "met from below", instead reflecting deeper societal transformations [8]. There is little research that connects the work happening in technologies for buildings and human-computer interaction. Thus, in this paper we suggest an agenda for linking new types of data to the challenge of sustainability as a problem that requires HCI and CSCW scholars to work across diverging concepts of sustainability. We argue for a stronger shared understanding of one type of technology for buildings, BIM, as a platform for engaging with technologies designed for interacting with buildings and show how HCI insights could help architects, engineers and builders design more responsively and more sustainably.

This transition to digitized construction over the past decade means that BIM, from a professional perspective, is now one of the most well-known and widespread collaborative technologies for digitized construction, particularly in large-scale domain specific projects. The rhetoric about BIM's impact outpaces its practical achievements and the tool remains relatively understudied [31]. BIM forms a unique platform for sustainability in construction because it supports various types of information. These include 3D geometries and 4D (time), as well as the industry labels of 5D (cost), 6D (facility management) and 7D (sustainability). BIM is the result of the evolution of Computer Aided Design (CAD), applied specifically to designing buildings. It is a digital platform and an operating methodology creating and managing building data [13]. While CAD was primarily used in design and engineering analysis, BIM helps to bring the utility of virtual design into successive stages of the process, including construction and facility management [4]. Centralizing all building data into a unique digital model, BIM can become a platform for design throughout the building's lifecycle. In the end, if complete and thus 'detailed' enough, BIM forms a 'digital twin' to the physical building that can be utilized throughout the building's lifetime as a platform for re-design by a broader range of stakeholders [31].

Several types of information are, by this point, fairly well represented in BIM tools including three-dimensional geometries (3D), construction time and schedules (4D) and cost (5D). However, information on facility management(6D) and sustainability (7D) are still underrepresented in BIM tools.

In this paper we present findings on the use of BIM based in a qualitative study of the initial design phase where a BIM platform is used to initiate a digital model of the building combined with interviews with domain experts working in large-scale projects across different communities of practice, including architects, engineers, designers, managers and constructors. In this context, we investigate how different types of information are supported by the database and digital BIM model—and what are the concrete challenges—when these different communities of practice work together to achieve sustainability. Furthermore, we draw on our different experiences engaging with BIM across contexts (US, Italy and Denmark) and disciplines as interdisciplinary scholars [11] [31] [44].

We focus on the following research questions: 1) what different concepts about sustainability are encoded into digitized construction, and 2) how do current models reflect the use of these concepts by the different communities of practice who collaborate to achieve sustainability goals? We investigate this in the context of BIM used in large-scale construction projects, namely hospitals and airports. These buildings projects are particularly complex to coordinate and include a changing and extensive team of different stakeholders [26] [31] [4]. Here, BIM represents a unique case for understanding how information platforms serve to help people coordinate work and solve difficult and ill-defined problems, including questions of sustainability. Increasingly, the embedded politics in decisions on a buildings design is gaining attention: in our case, UN Sustainable Development Goals [32] become one of the goals for collaborative work, as we will see.

We find that the communities of practice studied have diverging concepts about sustainability and energy simulation that live within different places in the project and which people enacted within different methodologies in the BIM model. Our findings suggest that a better integration and representation of the different forms of data—facilities management and sustainability data, in particular—can support the stronger shared concept of sustainability that is necessary for the tighter coupling of work to enable stakeholders to develop a shared practice and to push for more environmentally sustainable constructions.

The HCI and CSCW communities must continue to grapple with the challenges inherent to highly complex projects, this study suggests. Doing so will allow practitioners and scholars to understand what is possible when communities of practice collaborate across long-term projects. We call for more scholars to engage with the goals for sustainability, such as the UN Sustainable Development Goals [32] and wish to consider how we as a community can help remedy the negative impacts of industrialized society through the design of technologies that bring this concern to the fore as part of the day-to-day work of long-term design projects. Many things are required for society to put into practice the ambitious rhetoric around sustainability. Here we address one concrete way: the practices of digitized construction that can help scholars and designers of the built environment better address sustainability goals in their work. Normatively, many agree that the building design process needs to be changed to account for the environmental impacts over buildings' lifecycle. We show how HCI and CSCW scholars can contribute to that goal.

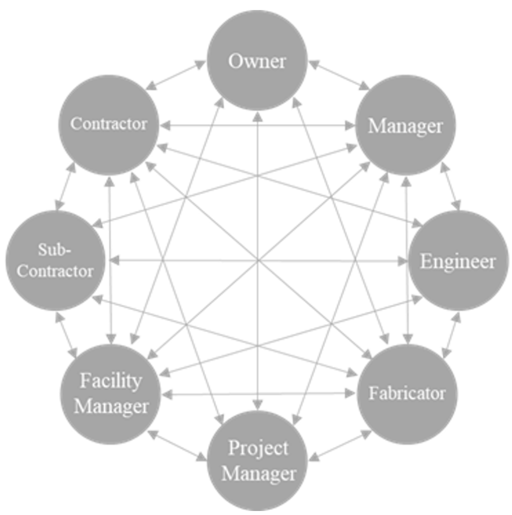
2 BUILDING INFORMATION MODELLING

Building Information Modeling (BIM) "is a digital tool and organizational process used to represent buildings in 3D digital models and databases and to facilitate coordination and communication within building projects, and it is at once a visualization tool for representing a building three-dimensionally; a database of building components that can be queried, filtered, and analyzed; a collaborative communication tool for linking the various teams of experts who work in the temporary project organization of commercial construction; a tool for translating discipline-specific software files; and a collection of datasets about a building that reflect the distinct disciplinary perspectives of architects, engineers, and builders" [33]. The possibilities for the content of this central database are related to various kinds of data. It includes not only what comes through BIM-software tools but can also contain data and documentation collected during the entire design, construction and facility management process.

From a practical perspective a BIM could be a network/project server within a single location or connected to multiple locations or a shared folder system in which data are stored only in the file itself. The possibility of having all the information gathered in a single "place" is thus one of the most interesting potentials of BIM. Using a BIM and sharing information between the various communities of practice and domain experts, collaborating to design and construct a building, can help ensure a tight coupling of work between members [13], [39] and in this sense ensure a substantial reduction of errors and duplications (figure 1).

BIM breaks with traditional ways of representing architectural and engineering design by including "information" about building elements along with geometric or representational values. In other words BIM is an "information" model that also stores data about the building design, construction and management processes (figure 2). Thus, one of the potentials of the BIM is that of being able to incorporate and coordinate more information associated with traditional 3D geometric modeling as a building is designed, constructed and repurposed. For this reason, when talking about BIM, scholars and practitioners talk about several dimensions, "Ds", or information layers. Specifically, each of these dimensions or layers include different aspects and information about the design process concerning:

- 4D when the time variable is analyzed, due to which construction and coordination activities can be optimized;
- 5D when the information present in the model is used to allow visualization of the progress of the activities and the relative management costs;
- 6D allows determining energy and sustainability estimates by basing the simulations on the technical characteristics of the elements that make up the building;
- 7D allows the operational management of the maintenance of the building and its components throughout its life cycle.



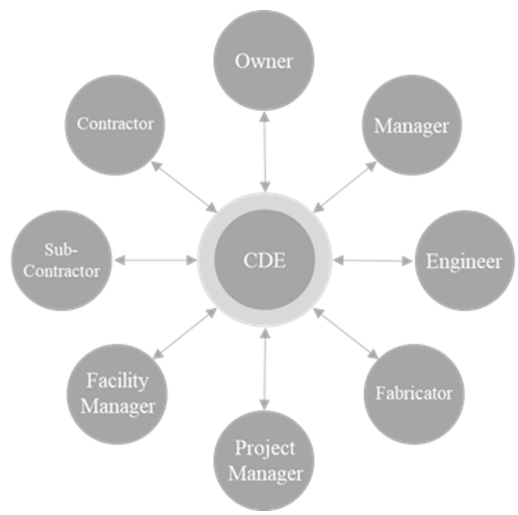


Fig. 1. Comparison of information exchange flows between the traditional sharing system (left) and the BIM model (right)

2.1 BIM and Sustainable Buildings

To understand BIM as a collaborative tool and platform in relation to sustainable construction—and potential research agendas—is critically related to its possibilities, including 1) Live models of buildings' infrastructure 2) 'Networked' infrastructure for buildings allowing for sensor integration etc. 3) New building features supporting the users work and/or living 4) The interaction between buildings and the city or landscape 5) Dynamic architecture and adaptive

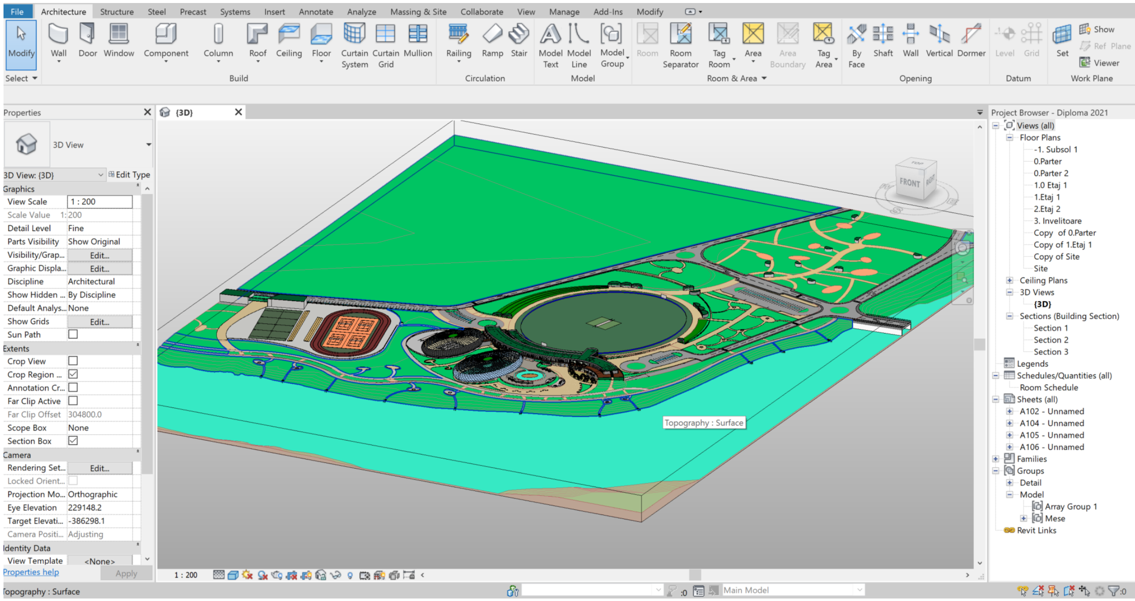


Fig. 2. A BIM model in Revit where one common data environment is shared across the communities of practice. Visuals vary depending on the perspective.

buildings, as pointed out by [18]. All these perspectives open up the design space making BIM a tool for thinking through agendas such as environmental sustainability throughout the life cycle of a building [44].

One of the topics that is most frequently dealt with in relation to sustainability is energy, in particular the energy performance of buildings. Building energy simulations are increasingly important during the design process to help architects and engineers optimize buildings' energy consumption [2] [16] [40] [43]. Several studies show that approximately 20 % of the design decisions made in the early design stage account for 80 % of the total impact on the final building energy performance [41]. In these early stages, the architects can make choices oriented towards sustainability. They also rely on the advice of specialized consultants and lean on "technical boundary spanners" to help translate sustainability goals into design [10]. In traditionally organized projects, the task of energy optimization is left for later design stages, done by engineers and energy consultants, when choices are made about the building's mechanical, electrical and plumbing systems [41] [29]. BIM provides the technical capacity for earlier collaboration between architects and the specialized community of practice of energy and sustainability experts.

Architects act first in a building project, by designing and defining all the details of the construction. Mechanical engineers are traditionally involved later when multiple decisions about the building have been already made (building's shape and orientation, number of windows or glazing, outside material or envelope…). Once architects pass the design phase, changes later in the pipeline become more difficult. And yet, that is exactly when energy consultants and other mechanical engineers are called upon to carry out detailed studies and simulations. The result is a lot of data, but very limited freedom for changes to the design.

Two decades ago, the main reasons why architectural firms did not use energy optimization tools in the design process were the clients' lack of understanding of energy optimization, tools high cost and insufficient staff training and skills due to steep learning curves and interfaces that would extend the design time [19]. Today, this situation has changed, and the tools are widely used in both architecture practices and engineering firms [28], [46], [3]. However, the assessment of energy optimization and analysis, is still a complex process that normally requires a great amount of effort, time and specialized skills. Energy optimization is normally conducted after the decision on major building elements or in the case were two to three alternative design solutions are modeled and compared [42] [43].

The challenge for the HCI and CSCW communities is that, for a variety of reasons, sustainability is transformed into a problem of trade-offs between costs and benefits. This frame promotes sustainability as a matter of individual action rather than dealing with the problems at scale. We are interested in shifting this challenge to understanding sustainability from a socio-technical perspective, focusing on how communities of practice around the work of designing and constructing sustainable buildings adapt and re-form and on how to bring human-centredness to technologies for buildings. With this paper we hope to bring knowledge about BIM to the larger HCI and CSCW communities. In what follows, we review literature on collaboration around digitized construction when BIM models provide us with a new type of platform for collaboration in large-scale projects.

3 THEORIZING COMMUNITIES OF PRACTICE, DIGITIZED CONSTRUCTION AND BIM

Recent studies investigate if and how BIM could be the new way to achieve a collaborative design and construction process [11]. Taking a socio-technical perspective it is clear how focusing on new types of interaction across communities of practice becomes critical for HCI and CSCW: if we are to solve the grand challenge of sustainability, it takes new approaches to design collaborative technologies in support of digitized construction.

Sustainability is poorly supported by BIM, it seems, when we begin to see this class of collaborative tools and platforms as common data environments. The consequence is a different point of engagement when seeing BIM as being shaped by what [14] call ‘data valences’. It is a new way to describe the differences expectations for data across communities of practice. Data values can change in multiple contexts, stakeholders and interactions between the communities of practice of a construction process. The data is an opportunity for conversation and connection between the communities of practice [27]. They can be challenged at the boundaries of the communities and can offer "voice" and expression for the development of approaches to translate the various values and expectations of people for the use of the data [34].

In a BIM-project dependencies and usual communication flows of a building project continuously change [38]. BIM, a product or intelligent digital representation of data about a facility, a collaborative process and a system of information exchanges, workflows and procedures [6], create new relations between different communities of practice [45]. All groups involved in the design processes (architects, engineer, builders) could be considered communities of practice, with the three characteristics defined by [45]: domain, community, and practice. These groups find themselves having to share work and information with others in a new way. The positive effects of using BIM are available [5] but there remain difficulties and limits.

Following prior research interested in expanding its agenda to address how to mitigate the problems of climate change and environmental sustainability [12] [24] this paper seeks to understand how different types of information are supported by the database and digital BIM model and what are the concrete challenges when these different communities of practice work together to achieve sustainability.

4 METHODS

We report an empirical and qualitative study based on data collection through interviews with domain experts in the construction sector. We were interested in understanding how they interpret the term sustainability in the context of digitized construction and how the different communities of practice in large scale projects work to achieve the objectives of environmentally sustainable project development. We interviewed domain experts to see if and how BIM digital models and construction project databases change the collaboration and coordination of different communities of practice.

Our starting point is a long-term field study (2016-2018) of the initial process of developing a BIM-model (112h). Later, we focused our data collection on sustainable construction (2019-2020) based in the observation that particularly the 6D and 7D dimension of BIM-models seem to be difficult to coordinate in large-scale projects. During these months one author interviewed experts on BIM and sustainability. The first author is also an engineer who is an expert in the field of BIM and energy simulations, the second author is an architect who has worked with BIM in practice for projects of various scales. The third and fourth authors have both conducted long-term field studies of BIM across the US, the UK and Denmark.

We conducted semi-structured interviews to guide a conversation with domain experts purposively selected for their knowledge of BIM, energy optimization and environmental sustainability in construction. In total, 5 domain experts were interviewed between May-October 2019, representing different communities of practice: architects (n=2), MEP engineer (n=1), researcher (n=1), and BIM manager (n=1).

Our intention in the qualitative study was to capture the categories of the domain experts, their subjective understandings of BIM as a collaborative tool, and their domain-specific concepts about sustainability [37], [20]. In this way the data provided us with a “trace” across topics (e.g. personal role and responsibility, experience with BIM, tools used, sustainability, energy simulation). All interviews started with some preliminary explanations to allow the interviewee to understand the purpose of the research, why they were chosen and why we are interested in their point of view and work experience. Interviews were recorded and then transcribed.

We conducted the analysis with social scientific rigor, drawing on Grounded Theory Method (GTM) [17] [25]. Our modified approach to grounded theory relied on an iterative development of interpretation and theory, using principles of constant comparison of data-with-data and data-with-theory [35]. The data analysis of the first interviews indicated that MEP engineers, architects and managers have different concepts about sustainability, on the one hand, and about energy optimization on the other hand. This guided our next round of data collection and analysis as we worked to understand what the concrete challenges to sustainable design and construction are and how they manifest in the use of BIM as a collaborative tool in large-scale projects.

5 ANALYSIS

"And then, just to tell it in a Greta Thunberg way, I see [BIM] as a process that allows you to conduct a reasoned design aimed at optimizing resources against waste [at the] construction site, encouraging a reduction in emissions. If I have more control upstream of the entire process, saving energy and conduct a correct and responsible design, [. . .] then [BIM] represents an evolution of the designer’s approach” (Interview with architect, 23 07 2019).

Despite a need for linking BIM to public agendas, as one of our interviewees put it, in a Greta Thunberg way, all the interviewees talked about the use of BIM from a technical point of view, describing practical aspects of it and of their work with the new kinds of tools. Our goal was to see how our respondents thought about the relationship between BIM as a new type of information coordination and collaboration for sustainability goals in order to understand 1) the different concepts about sustainability in digitized construction, and 2) how current models reflect the use of these concepts by different communities of practice who collaborate to achieve sustainability goals?

5.1 Building Information Modeling: New Process or New Technology?

In the study, responses of the experts we interviewed focused on the tools for modelling and on the formats of data exchange. More importantly, they identified how new collaborative processes emerged with the new technologies. As an architect working with sustainability explained, a 'BIM approach' is a method that changes both the professional and the collaboration process, making it so that 'you can hardly do things as before': "The other day I had to work on a "no-BIM project" and I realized the waste of time and confusion that you have without a BIM approach: once you discover this method you can hardly do things as before." (Interview with architect, 23 07 2019).

This opens the question of whether we are talking about BIM as a new technology or a new process. We asked this question to all our respondents. This approach placed a lot of hope onto the potential for how improvements in the building process could lead to more sustainable construction, as illustrated by the opening quote. Taking this approach allows the architect to conduct a reasoned design and have more control upstream of the entire process, saving energy and creating more correct and responsible designs. BIM as a new process, in our interviews, entailed our respondents describing new features of the design process managed for a BIM perspective. For example, a BIM manager explained,

"[The] process is more complicated. This is not just purchasing a BIM license and start drawing using it. It's to understand what the clients expects from BIM, what are the BIM goals because is not the same if you want to produce drawing, if you want to coordinate, if you want to extract quantities… So, the question is 'what for'?" (Interview with BIM manager, 13 09 2019).

The example that one of our respondents gave is that we are currently in the situation where one wants a new car but does not know the specifications and therefore does not know how to choose it. And so, clients and policymakers push for BIM to be used, but people do not know exactly for what. This points to the lack of human-centredness experienced in different ways by different professionals: for modelling the project in 3D, for improving communication across the communities of practice involved in large-scale projects, for coordinating among the subcontractors who build different systems, or for extracting data for use in other kinds of simulations and analysis.

The technical affordances of BIM for teams in large-scale projects were clear. The teams represented in our interviews used strategies to 'ensure the correctness and correspondence of the data entered in the model', to organize and to 'facilitate communication' and 'information exchange between the different teams', and to adopt 'to classify everything' using Work Breakdown Structure, a project management methodology to organize work in more easily manageable elements.

BIM as a technical innovation helps to create new opportunities for improving construction. BIM as a process innovation brings teams together for collaboration in unprecedented ways, including tackling one of society's biggest challenges. To be fair, we pushed for respondents in our semi-structured interviews to consider what BIM could do for sustainability. However, our respondents focused on how BIM's true innovation relies on the transformation of the common data environment and the potential to change how communication, coordination and collaboration occurs on design and building projects, and these, too, may help improve the sustainability of construction.

5.2 Sustainability

Each interviewee was clear on the need for reaching sustainability goals, but each had a different point of view on what needs to be done to facilitate the inclusion of these aspects in the building design process. Many elements influence achieving sustainability goals in a building project. One of the surprising things that emerged from our interviews is that there are key problems related to sustainability of the 'time' that designers and builders work on it. We interviewed a researcher who is an expert in European sustainable construction project, who phrased the challenge this way, "Why does sustainability come always after? The process is usually a kind of cascade process—something obviously that we notice in all the projects. Sustainability and energy are not a priority for the users. So, they have some other priorities, so usually the designers also start with these and then, once something of the priorities of the users have been solved, then a kind of cascade effects start to calculate other things, calculating the compliant with energy regulations, … But it is something that comes after, always." (Interview with researcher, 13 09 2019).

This problem of looking holistically at the environmental impact of the project was echoed throughout our interviews. The BIM manager explains the consequences of addressing the sustainability/energy aspects at the end of the design and building process, "So, at the end of the project you are only able to maybe change the type of glass, maybe add some protections… so you have a small margin to modify the project" (Interview with BIM manager, 13 09 2019).

Creating a BIM model across the design and construction team has the potential to help teams make more sustainable choices. One of the obstacles to that in current practice is that BIM is used more commonly when design is relatively finished and constructors and subcontractors coordinate the final mechanical design (MEP coordination) through the 'clash detection' affordances of BIM modelling. However, our interviewees talk about how BIM could contribute to lifecycle analysis of the sustainability of design and construction choices. Making sustainable design choices means designers and builders consider many aspects and are ready to make changes, adaptations or modifications to the project to meet sustainability goals.

In theory, improvements to the process brought about by BIM could create the possibilities for analysis earlier in the project. A human-centred approach from this perspective suggests a broader concept of sustainability. There is hope that earlier and improved access 'data' would help with designing for sustainability. The researcher said,

"But there is a big gap on exploiting all this information and all these data … It should be quite easy to integrate all these data and then to have a kind of tool that is able to exploit these data and to calculate some values or some indicators. In the sense, it could support also the designer when they have to select options, if Revit could put these indicators automatically with all the data and information that are inside the model." (Interview with researcher, 13 09 2019).

The idea is that just as BIM currently automates clash detection, a suite of tools could help do simplified analysis of environmental and energy impacts on models. But getting from data on environmentally sustainable projects to decisions about those projects entails "technical boundary spanners" [10] who can bridge the differences across communities of practice and the narrative sense making [36] to get teams to enact those decisions.

The BIM manager recognized the challenges of expanding the scope for data-driven innovation with BIM. The first challenge is the cost entailed to set up the data environment for analysis in the first place. 'If we want a real 5D, 6D and 7D (integrated cost, facility management and environmental analysis in BIM), we will need to increase the project cost but we will get a richer project to make all other wonderful Ds.' He continued, "Passing to more Ds means more data. You have to think how to manage it and you have to care of this data… The challenge is the 'data.' It demands new roles in the project." (Interview with BIM manager, 13 09 2019).

The potential for BIM data to be used for analysis to support environmental impact analysis is there but it requires potentially more time, money and analysis in order to use it for decision making. Still, our interviews suggested that the data could 'drive' these kinds of activities for the building design and construction. The researcher suggested that architects could have a BIM-enabled tool that "gives you some kind of indication on all these different parameters, not only about cost or other things considered from the beginning, but also about environmental and sustainability" (Interview with researcher, 13 09 2019).

6 DISCUSSION AND CLOSING REMARKS

BIM is an important innovation that will drive fundamental changes in the architecture, engineering and construction industries. BIM as a technological innovation is already affording new ways of collaborating and communicating on large-scale projects and as the platform underlying 'smart' cities. As a process innovation, BIM will continue in the coming decades to change the field, according to experts. New understanding of what forms the challenges to sustainability as a concept that continue to develop also in respect to those who will at some point be the subjects to interactive 'smart' buildings are critical to consider.

Bringing human-centredness to BIM is a first critical starting point and how we can accommodate diverging concepts on sustainability that currently live-in different places of the design and construction process. The use of BIM continues to expand. BIM is a useful platform for coordinating among a broad and varying set of ideas and stakeholders. In tackling the wicked problem of sustainability [30], breaking down traditional domain boundaries and coming up with new design methods which entangle different fields and stakeholders [22] [21] becomes paramount.

The common data environment is one of the main reasons for using BIM. In this environment, it is possible to share the model, adapt metadata, explain and provide context on the project timeline and exchange and comment on models. New services become available including immersive environments to simulate the consequences of changes in the environment or use of a building [4]. These experiences are still highly focused on professional communities, rather than broader groups of potential building users or publics.

In this paper we point to concrete openings for the broader HCI and CSCW communities to bring human-centredness to technologies for buildings. Specifically, we propose an agenda for linking new types of data to the challenge of sustainability that takes seriously the need for making BIM available to a broader audience including (but not limited to):

(1) Building a shared vocabulary for sustainable construction across communities of practice
(2) Broaden schemes for 6D and 7D dimensions in BIM to encompass civic perspectives
(3) Enable new types of data and power to enter design processes for a more participatory advocacy for sustainability

There are still several challenges for using BIM as a common data environment in practice: the data valences across communities of practice concerned with sustainability is one particular challenge, we find. While our interviewees mentioned how mechanical coordination occurs in BIM, we are still very early in the adoption process in terms of architects and engineers using a shared model. Shared BIM models provide the opportunity for analyses like energy optimization to occur more readily and more easily when it is an articulated value. Different communities of practice can work in new ways collaborative and small companies can work on bigger, global projects thanks to BIM.

BIM has the potential to shift the focus away from what [12] point to as the dominant understanding of sustainability as a matter of personal morality. BIM invites the kind of industrial regulation that is one parameter that could enable more sustainable construction at scale. The coordination is another answer to the question, even though there are still technical constraints and difficulties in implementing full coordination of different kinds of expertise on projects. Better coordination and resolution of multiple problems related to sustainability and interventions already at the design stage, without waiting for them to appear on construction site, leads to a stronger focus on the design for sustainable construction.

The benefits are that in terms of technical innovation and process innovation, BIM represents a step toward improved energy efficiency and environmental sustainability of buildings and the building process. Yet, the political mobilization aspect is missing as BIM remains a highly professionalized tool and platform. Critical perspectives on 'smart' cities and public debate are not easily 'married' with collaborative tools such as BIM, [7] [23] others show. An agenda for linking new types of data to the challenge of sustainability requires scholars to begin engaging with BIM not only as a professional tool for collaboration but as a scene for the politics around human-centredness to technologies for buildings.

This is a clear case of the HCI and CSCW communities having the capacity to help a community of practice in their efforts to solve a major societal problem: design and construction for environmental sustainability. While improving the collaborative process in building design and construction will not alone solve the climate crisis, there is a clear way that we as a community can use our skills to have a real-world impact on working toward sustainability goals. In building communities of practice, improved collaboration is an issue of environmental sustainability.

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